SYSTEM AND METHOD FOR MULTIPLE WELLS FROM A COMMON SURFACE LOCATION

TECHNICAL FIELD

The present invention relates generally to the field of subterranean exploration and drilling and, more particularly, to a system and method for multiple wells from a common surface location.

BACKGROUND

Subterranean deposits of coal contain substantial quantities of entrained methane gas. Limited production in use of methane gas from coal deposits has occurred for many years. Substantial obstacles, however, have frustrated more extensive development in use of methane gas deposits in coal seams. The foremost problem in producing methane gas from coal seams is that while coal seams may extend over large areas of up to several thousand acres, the coal seams are fairly shallow in depth, varying from a few inches to several meters. Thus, while the coal seams are often relatively near the surface, vertical wells drilling into the coal deposits for obtaining methane gas can only drain a fairly small radius around the coal deposits. Further, coal deposits are not amenable to pressure fracturing and other methods often used for increasing methane gas production from rock formations. As a result, once the gas easily drained from a vertical well bore in a coal seam is produced further production is limited in volume. Additionally, coal seams are often associated with subterranean water, which must be drained from the coal seam in order to produce the methane.

Horizontal drilling patterns have been tried in order to extend the amount of coal seams exposed to a drill bore for gas extraction. Such horizontal drilling techniques, however, require the use of a radiused well bore which presents difficulties in removing the entrained water from the coal seams. The most efficient method for pumping water from a subterranean well, a sucker rod pump, does not work well in horizontal or radiused bores.

SUMMARY

The present invention provides a system and method using multiple articulated and drainage wells from a common surface well that substantially eliminates, reduces, or minimizes the disadvantages and problems associated with previous systems and methods. In particular, certain embodiments of the present invention provide a system and method using multiple articulated and drainage wells from a single surface well for efficiently producing and removing entrained methane gas and water from a coal seam without requiring that multiple wells be drilled from the surface.

In accordance with one embodiment of the present invention, a system for accessing a subterranean zone from an entry well including an entry well extending from the surface. The entry well has a substantially vertical portion. One or more drainage wells extend from the entry well to a subterranean zone. One or more articulated wells extend from the entry well to the subterranean zone. At least one of the articulated wells intersects at least one of the one or more drainage wells at a junction proximate the subterranean zone. A drainage pattern is formed coupled to the junction and operable to conduct fluids from the subterranean zone to the junction.

The technical advantage of the present invention include providing a method and system for using multiple articulated and drainage wells from a common surface well. In particular, a technical advantage may include the formation of an entry well, a plurality of drainage wells, a plurality of articulated wells, and drainage patterns from a single surface location to minimize the number of surface wells needed to access a subterranean zone for draining of gas and liquid resources. This allows for more efficient drilling and production and greatly reduces costs and problems associated with other systems and methods.

Other technical advantages of the present invention will be readily apparent to one skilled in the art from the following figures, description, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like numerals represent like parts, in which:

FIGURE 1 is a cross-sectional diagram illustrating a system for accessing a subterranean zone through multiple wells drilled from a common surface well;

FIGURE 2 is a cross-sectional diagram illustrating production of fluids from a subterranean zone through a well bore system in accordance with one embodiment of the present invention;

FIGURE 3 illustrates one embodiment of subterranean drainage patterns of the well system of FIGURE 2;

FIGURE 4 illustrates an example method for producing fluids from a subterranean zone using the well bore system of FIGURE 1;

FIGURE 5A illustrates construction of an example guide tube bundle for insertion into entry well of FIGURE 1; and

FIGURE 5B illustrates an example entry well with an installed guide tube bundle.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a diagram illustrating a system 10 for accessing a subterranean zone using multiple articulated and drainage wells from a common surface well in accordance with an embodiment of the present invention. In particular embodiments, the subterranean zone is a coal seam. However, it should be understood that other subterranean zones can be similarly accessed using system 10 of the present invention to remove and/or produce water, hydrocarbons and other fluids from the zone, to treat minerals in the zone prior to mining operations, or to inject, introduce, or store a fluid or other substance into the zone.

Referring to FIGURE 1, system 10 includes an entry well 12, drainage wells 14, articulated wells 16, cavities 18, and sumps 20. Entry well 12 extends from surface 22 towards subterranean zone 24. Drainage wells 14 extend from the terminus of entry well 12 to subterranean zone 24, although drainage wells 14 may alternatively extend from any other suitable portion of entry well 12. Articulated wells 16 also may extend from the terminus of entry well 12 to subterranean zone 24 and may each intersect a corresponding drainage well 14. Cavity 18 and sump 20 may be located at the intersection of an articulated well 16 and a corresponding drainage well 14.

Entry well 12 is illustrated as being substantially vertical; however, it should be understood that entry well 12 may be formed at any suitable angle relative to surface 22 to accommodate, for example, surface geometries and attitudes and/or the geometric configuration or attitude of a subterranean resource. In the illustrated embodiment, drainage wells 14 are formed as slant wells that angle away from entry well 12 at an angle designated α. The angle α depends, in part, on the depth of subterranean zone 24. It will be understood that drainage wells 14 may be formed at other angles to accommodate surface topologies and other factors similar to those affecting entry well 12. Furthermore, although drainage wells 14 are illustrated as having the same angle of slant over their entire length (below entry well 12), drainage wells 14 may have two or more portions below entry well 12 that are at different angles. For example, the portion of drainage wells 14 from which cavity 18 is formed and/or which is intersected by the corresponding articulated well 16 may be substantially vertical. In the illustrated embodiment, drainage wells 14 are formed in

relation to each other at an angular separation of β degrees. In one embodiment, the angle β equals twice the angle α. It will be understood that drainage wells 14 may be separated by other angles depending likewise on the topology and geography of the area and location of subterranean zone 24.

In particular embodiments, an enlarged cavity 18 may be formed from each drainage well 14 at the level of subterranean zone 24. As described in more detail below, cavity 18 provides a junction for the intersection of drainage well 14 by a corresponding articulated well 16 used to form a subterranean drainage bore pattern in subterranean zone 24. Cavity 18 also provides a collection point for fluids drained from subterranean zone 24 during production operations. In one embodiment, cavity 18 has a radius of approximately eight feet; however, any appropriate diameter cavity may be used. Cavity 18 may be formed using suitable under-reaming techniques and equipment. A portion of drainage well 14 may continue below cavity 18 to form a sump 20 for cavity 18. Although cavities 18 and sumps 20 are illustrated, it should be understood that particular embodiments do not include a cavity and/or a sump.

Each articulated well 16 extends from the terminus of entry well 12 to cavity 18 of a corresponding drainage well 14 (or to the drainage well 14 if no cavity is formed). Each articulated well 16 includes a first portion 34, a second portion 38, and a curved or radiused portion 36 interconnecting portions 34 and 38. In FIGURE 1, portion 34 is illustrated substantially vertical; however, it should be understood that portion 34 may be formed at any suitable angle relative to surface 22 to accommodate surface 22 geometric characteristics and attitudes and/or the geometric configuration or attitude of subterranean zone 24. Portion 38 lies substantially in the plane of subterranean zone 24 and intersects the large diameter cavity 18 of a corresponding drainage well 14. In FIGURE 1, the plane of subterranean zone 24 is illustrated substantially horizontal, thereby resulting in a substantially horizontal portion 38; however, it should be understood that portion 38 may be formed at any suitable angle relative to surface 22 to accommodate the geometric characteristics of subterranean zone 24. Each articulated well 16 may be drilled using an articulated drill string 26 that includes a suitable down-hole motor and a drill bit 28. A measurement while drilling (MWD) device 30 may be included in articulated drill string 26 for

controlling the orientation and direction of a well bore drilled by the motor and bit 28. Any suitable portion of articulated well 16 may be lined with a suitable casing.

In the illustrated embodiment, drainage well 14 is sufficiently angled away from a corresponding articulated well 16 to permit the large radiused curved portion 36 and any desired portion 38 to be drilled before intersecting cavity 18. In particular embodiments, curved portion 36 may have a radius of one hundred to one hundred fifty feet; however, any suitable radius may be used. This angle α may be chosen to minimize the angle of curved portion 36 to reduce friction in articulated well 16 during drilling operations. As a result, the length of articulated well 16 is maximized.

After cavity 18 has been successfully intersected by articulated well 16, drilling is continued through cavity 18 using articulated well string 26 to provide a drainage bore pattern 32 in subterranean zone 24. In FIGURE 1, drainage bore pattern 32 is illustrated substantially horizontal corresponding to a substantially horizontally illustrated subterranean zone 24; however, it should be understood that drainage bore pattern 32 may be formed at any suitable angle corresponding to the geometric characteristics of subterranean zone 24. During this operation, gamma ray logging tools and conventional MWD devices may be employed to control and direct the orientation of drill bit 28 to retain drainage bore pattern 32 within the confines of subterranean zone 24 and to provide substantially uniform coverage of a desired area within subterranean zone 24. Drainage bore pattern 32 may comprise a single drainage bore extending into subterranean zone 24 or it may comprise a plurality of drainage bores. Further information regarding an example drainage bore pattern 32 is described in more detail below. In addition, although pattern 32 is illustrated as extending from cavity 18, portion 38 of articulated wells 16 may be extended appropriately so that portion 38 serves the function of draining fluids from the subterranean zone 24.

During the process of drilling drainage bore pattern 32 in a coal seam or other appropriate formations, drilling fluid or "mud" may be pumped down articulated drill string 26 and circulated out of drill string 26 in the vicinity of a bit 28, where it is used to scour the formation and to remove formation cuttings. The cuttings are then entrained in the drilling fluid which circulates up through the annulus between drill string 26 and the walls of articulated well 16 until it reaches surface 22, where the

cuttings are removed from the drilling fluid and the fluid is then recirculated. This conventional drilling operation produces a standard column of drilling fluid having a vertical height equal to the depth of articulated well 16 and produces a hydrostatic pressure on the well bore corresponding to the well bore depth. Because coal seams tend to be porous and fractured, they may be unable to sustain such hydrostatic pressure, even if formation water is also present in subterranean zone 24. Accordingly, if the full hydrostatic pressure is allowed to act on subterranean zone 24, the result may be loss of drilling fluid in entrained cuttings into the formation. Such a circumstance is referred to as an "over-balanced" drilling operation in which they hydrostatic fluid pressured in the well bore exceeds the ability of the formation to withstand the pressure. Loss of drilling fluids and cuttings into the formation not only is expensive in terms of the lost drilling fluids, which must be made up, but also tends to plug the pores in subterranean zone 24, which are needed to drain the coal seam of gas and water.

To prevent over-balanced drilling conditions during formation of drainage bore pattern 32, air compressors or other suitable pumps may be provided to circulate compressed air or other suitable fluids down drainage wells 14 and back up through corresponding articulated wells 16. The circulated air or other fluid will mix with the drilling fluid in the annulus around the articulated drill string 26 and create bubbles throughout the column of drilling fluid. This has the effect of lightening the hydrostatic pressure of the drilling fluid and reducing the down-hole pressure significantly that drilling conditions do not become over-balanced. Aeration of the drilling fluid reduces down-hole pressure to approximately 150-200 pounds per square inch (psi). Accordingly, low pressure coal seams and other subterranean zones can be drilled without substantial loss of drilling fluid and contamination of the zone by the drilling fluid. Alternatively, tubing may be inserted into drainage well 14 such that air pumped down through the tubing forces the fluid back through the annulus between the tubing and drainage well 14.

In yet another embodiment, a pumping 40 may be installed in cavity 18, as illustrated in FIGURE 1, to pump drilling fluid and cuttings to surface 22 through drainage well 14. This eliminates the friction of air and fluid returning through articulated well 16 and may reduce down-hole pressure to nearly zero.

Foam, which may be compressed air mixed with water, may also be circulated down through the articulated drill string 26 along with the drilling mud in order to aerate the drilling fluid in the annulus as articulated well 16 is being drilled and, if desired, as drainage bore pattern 32 is being drilled. Drilling of drainage bore pattern 32 with the use of an air hammer bit or an air-powered down-hole motor will also supply compressed air or foam to the drilling fluid. In this case, the compressed air or foam which is used to power the down-hole motor and bit 28 exits articulated drill string 26 in the vicinity of drill bit 28. However, the larger volume of air which can be circulated down drainage wells 14 permits greater aeration of the drilling fluid than generally is possible by air supplied through articulated drill string 26.

FIGURE 2 illustrates production of fluids from drainage bore pattern 32a and 32b in subterranean zone 24 in accordance with one embodiment of the present invention. In this embodiment, after wells 14 and 16, respectively, as well as desired drainage bore patterns 32, have been drilled, articulated drill string 26 is removed from articulated wells 16. In particular embodiments, articulate wells may be suitably plugged to prevent gas from flowing through articulate wells 16 to the surface 22.

Referring to FIGURE 2, the inlets for down-hole pumps 40 or other suitable pumping mechanisms are disposed in drainage wells 14 in their respective cavities 18. Each cavity 18 provides a reservoir for accumulated fluids allowing intermittent pumping without adverse effects of a hydrostatic head caused by accumulated fluids in the well bore. Each cavity 18 also provides a chamber for gas/water separation for fluids accumulated from drainage bore patterns 32.

Each down-hole pump 40 is connected to surface 22 via a respective tubing string 42 and may be powered by sucker rods extending down through wells 14 of tubing strings 42. Sucker rods are reciprocated by a suitable surface mounted apparatus, such as a powered walking beam 46 to operate each down-hole pump 40. Each down-hole pump 40 is used to remove water and entrained coal finds from subterranean zone 24 via drainage bore patterns 32. In the case of a coal seam, once the water is removed to the surface, it may be treated for separation of methane which may be dissolved in the water and for removal of entrained finds. After sufficient water has been removed from subterranean zone 24, pure coal seam gas may be allowed to flow to surface 22 through the annulus of wells 14 around tubing strings 42

and removed via piping attached to a well head apparatus. At surface 22, the methane is treated, compressed and pumped through a pipeline for use as fuel in a conventional manner. Each down-hole pump 40 may be operated continuously or as needed to remove water drained from subterranean zone 24 into cavities 18.

FIGURE 3 illustrates one embodiment of the subterranean patterns 32a and 32b for accessing subterranean zone 24 or other subterranean zone. The patterns 32a and 32b may be used to remove or inject water, gas or other fluids. The subterranean patterns 32a and 32b each comprise a multi-lateral pattern that has a main bore with generally symmetrically arranged and appropriately spaced laterals extending from each side of the main bore. As used herein, the term each means every one of at least a subset of the identified items. It will be understood that other suitable multi-branching or other patterns including or connected to a surface production bore may be used. For example, the patterns 32a and 32b may each comprise a single main bore. Referring to FIGURE 3, patterns 32a and 32b each include a main bore 150 extending from a corresponding cavity 18a or 18b, respectively, or intersecting wells 14 or 16 along a center of a coverage area to a distal end of the coverage area. The main bore 150 includes one or more primary lateral bores 152 extending from the main bore 150 to at least approximately to the periphery of the coverage area. The primary lateral bores 152 may extend from opposite sides of the main bore 150. The primary lateral bores 152 may mirror each other on opposite sides of the main bore 150 or may be offset from each other along the main bore 150. Each of the primary lateral bores 152 may include a radiused curving portion extending from the main bore 150 and a straight portion formed after the curved portion has reached a desired orientation. For uniform coverage, the primary lateral bores 152 may be substantially evenly spaced on each side of the main bore 150 and extend from the main bore 150 at an angle of approximately forty-five degrees. The primary lateral bores 152 may be shortened in length based on progression away from the corresponding cavity 18a or 18b. Accordingly, the distance between the cavity or intersecting well bore and the distal end of each primary lateral bore 152 through the pattern may be substantially equally for each primary lateral 152.

One or more secondary lateral bores 152 may be formed off one or more of the primary lateral bores 152. In a particular embodiment, a set of secondary laterals

154 may be formed off the primary lateral bores 152 of each pattern 32a and 32b closest to the corresponding cavity 18a and 18b. The secondary laterals 154 may provide coverage in the area between the primary lateral bores 152 of patterns 32a and 32b. In a particular embodiment, a first primary lateral 154 may include a reversed radius section to provide more uniform coverage of subterranean zone 24.

The subterranean patterns 32a and 32b with their central bore and generally symmetrically arranged and appropriately spaced auxiliary bores on each side may provide a substantial uniform pattern for draining fluids from subterranean zone 24 or other subterranean zone. The number and spacing of the lateral bores may be adjusted depending on the absolute, relative and/or effective permeability of the coal seam and the size of the area covered by the pattern. The area covered by the pattern may be the area drained by the pattern, the area of a spacing unit that the pattern is designed to drain, the area within the distal points or periphery of the pattern and/or the area within the periphery of the pattern as well as surrounding area out to a periphery intermediate to adjacent or neighboring patterns. The coverage area may also include the depth, or thickness of the coal seam or, for thick coal seams, a portion of the thickness of the seam. Thus, the pattern may include upward or downward extending branches in addition to horizontal branches. The coverage area may be a square, other quadrilateral, or other polygon, circular, oval or other ellipsoid or grid area and may be nested with other patterns of the same or similar type. It will be understood that other suitable drainage bore patterns may be used.

As previously described, the well bore 150 and the lateral bores 152 and 154 of patterns 32a and 32b are formed by drilling through the corresponding cavity 18a or 18b using the drill string 26 in appropriate drilling apparatus. During this operation, gamma ray logging tools and conventional MWD technologies may be employed to control the direction and orientation of drill bit 28 so as to retain the drainage bore pattern within the confines of subterranean zone 24 and to maintain proper spacing and orientation of wells 150 and 152. In a particular embodiment, the main well bore 150 of each pattern 32a and 32b is drilled with an incline at each of the plurality of lateral branch points 156. After the main well bore 150 is complete, the drill string 26 is backed up to each successive lateral point 156 from which a primary lateral bore 152 is drilled on each side of the well bore 150. The secondary

laterals 154 may be similarly formed. It will be understood that the subterranean patterns 32a and 32b may be otherwise suitably formed. Furthermore, as described above, a pattern (as illustrated in FIGURE 3) or otherwise may be formed off of portion 38 of articulated well 16 (which would function as well bore 150) such that cavities 18 are located at the end of portion 38/well bore 150.

FIGURE 4 is a flow diagram illustrating a method for preparing subterranean zone 24 for mining operations in accordance with particular embodiments of the present invention. The example method begins at step 400 in which entry well 12 is drilled substantially vertically from the surface. At step 402, a casing with guide tubes is installed into the entry well 12. At step 404, the casing is cemented in place inside entry well 12.

At step 406, drill string 26 is inserted through entry well 12 and one of the guide tubes in the guide tube bundle. At step 408, drill string 26 is used to drill approximately fifty feet past the casing. At step 410, the drill is oriented to the desired angle of the drainage well 14 and, at step 412, drainage well bore 14 is drilled down into and through target subterranean zone 24.

At step 414, down-hole logging equipment may be utilized to identify the location of the subterranean zone 24. At step 416, cavity 18a is formed in first drainage well 14 at the location of subterranean zone 24. As previously discussed, cavity 18 may be formed by underreaming and other conventional techniques. At decisional step 418, if additional drainage wells are to be drilled, the method returns to step 406. If no additional drainage wells 14 are to be drilled, then the method proceeds to step 420.

At step 420, articulated well 16 is drilled to intersect cavity 18. At step 422, drainage bore pattern 32 is drilled into subterranean zone 24. At step 424, production equipment is installed into drainage wells 14 and at step 426 the process ends with the production of fluids (such as water and gas) from the subterranean zone 24.

Although the steps have been described in a certain order, it will be understood that they may be performed in any other appropriate order. Furthermore, one or more steps may be omitted, or additional steps performed, as appropriate.

FIGURE 5A illustrates formation of a casing with associated guide tube bundle as described in step 402 of FIGURE 4. Three guide tubes 48 are shown in side

view and end view. The guide tubes 48 are arranged so that they are parallel to one another. In the illustrated embodiment, guide tubes 48 are 9 5/8" joint casings. It will be understood that other suitable materials may be employed. As an example, guide tubes 48a and 48b serve as the tubes through which drainage wells 14a and 14b are drilled, respectively. In this example, guide tube 48c serves as the tube through which both articulated wells 16a and 16b are drilled. It will be understood that other suitable arrangements may be employed. In another embodiment, guide tubes 48 may be attached to a casing collar such that the guide tubes 48 and casing collar make up the guide tube bundle.

FIGURE 5B illustrates entry well 12 with guide tubes 48 and a casing collar 50 cemented in entry well 12. Entry well 12 is formed from the surface 22 to a target depth (in particular embodiments, approximately three hundred feet). In a particular embodiment, entry well 12 has a diameter of approximately twenty-four inches. Forming entry well 12 corresponds with step 400 of FIGURE 4. Guide tubes 48 are shown attached to a casing collar 50. Casing collar 50 may be any casing suitable for use in down-hole operations. Inserting casing collar 50 and guide tubes 48 into entry well 12 corresponds with step 402 of FIGURE 4.

Corresponding with step 404 of FIGURE 4, a cement retainer 52 is poured or otherwise installed around the casing inside entry well 12. The cement casing may be any mixture or substance otherwise suitable to maintain casing 50 in the desired position with respect to entry well 12.

In operation, drill string 26 is positioned to enter one of the guide tubes 48. In order to keep drill string 26 relatively centered in casing 50, a stabilizer 54 may be employed. Stabilizer 54 may be a ring and fin type stabilizer or any other stabilizer suitable to keep drill string 26 relatively centered. To keep stabilizer 54 at a desired depth in well bore 12, stop ring 56 may be employed. Stop ring 56 may be constructed of rubber or metal or any other foreign down-hole environment material suitable. Drill string 26 may be inserted randomly into any of a plurality of guide tubes 48, or drill string 26 may be directed into a selected guide tube 48a. This corresponds to step 406 of FIGURE 4.

Although the present invention has been described with several embodiments, various changes and modifications may be suggested to one skilled in the art. It is

intended that the present invention encompass such changes and modifications as fall within the scope of the appended claims.